ALUMINUM

Project Fact Sheet

Numerical Modeling of Transient Melt Flows

Benefits

- Total annual economic savings between $20 and $100 million
- Potential energy savings of twenty percent
- The model will help to reduce or completely eliminate current PFC emissions

Applications

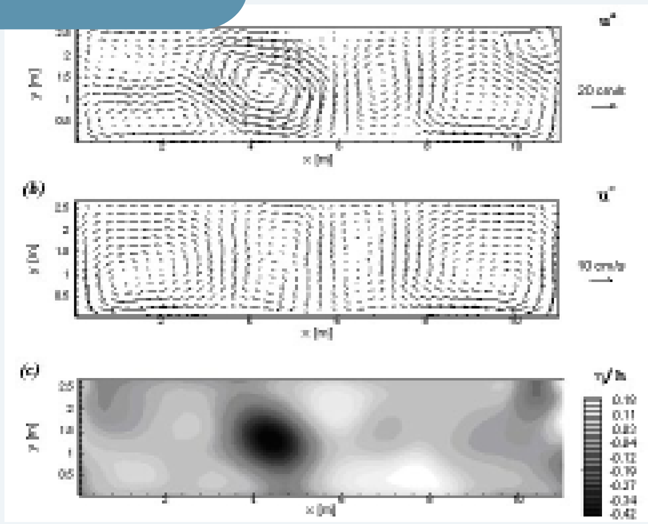
The modeling tool and understanding gained from this research will further the ability of the domestic aluminum industry to remain competitive through improvements to the magnetic design of its cells, either for retrofits, or brownfield applications.

Numerical Modeling of Transient Melt Flows and Interface Instability in Aluminum Reduction Cells

Current performance of domestic primary aluminum production is determined by a significant share of older plants. Even though these plants typically have lower capital expenses, they generally have higher energy consumption per unit of aluminum produced than smelters using newer designs making them less competitive. A key determinant in the energy consumption of aluminum smelting pots is the magnetohydrodynamic (MHD) stability of the metal pad/electrolyte interface. More stable designs permit operation at lower anode-to-cathode spacing, thus decreasing power consumption. More stable MHD designs also control anode effects which contribute to lost productivity and release of fluorine-based greenhouse gases. Incorporating new knowledge to allow better control of MHD effects in existing and design retrofit plants in the domestic smelting industry would decrease energy consumption.

This research addresses the MHD induced melt flow and interface instabilities in aluminum reduction cells. The goal is to develop a tool useful for the analysis of MHD instabilities in smelting cells and then use it to gain understanding of the origin and nature of the MHD instabilities. The partners will develop an accurate and computationally efficient mathematical model that will incorporate substantially more relevant physics than the existing models. In particular, the melt flows and interface instability will be treated as coupled nonlinear nonsteady processes. An accurate mathematical model will help to achieve more stable design of the reduction smelters. This will lower the anode-to-cathode distance, thus reducing the energy consumption.

Transient Melt Flows



Results of the simulations of melt flows in a simplified P-255 reduction cell. Distributions of velocity in metal pad (a), electrolyte (b), and interface deformation (c) are shown.

Project Description

Goal: The goal of this research is to develop a tool useful for the analysis of magnetohydrodynamic (MHD) instabilities in smelting cells to lower the anode-to-cathode spacing and use it to gain understanding of the origin and nature of the MHD instabilities.

Progress and Milestones

TASK I - Develop working modeling tool.

- Transform existing numerical algorithms into a form suitable for efficient simulation of realistic smelter configurations.
- Calibrate and validate the model.

TASK II - Investigate the fundamental properties of melts flows and interface fluctuations.

- Perform simulations to reveal the reasons and conditions for the time variations of the horizontal velocity in aluminum and electrolyte.
- Perform simulations with typical configurations of magnetic fields and electric currents to reveal the dependence of fundamental stability characteristics on the details of smelter design.

TASK III - Improve the cell design using the developed model and acquired understanding of MHD processes.

- Simulate older smelter conditions with the purpose of analyzing retrofit options.
- Improve the energetic and environmental quality of the design solution for a new large cell.
- Simulate MHD properties of a cell with known frequent anode effects to reveal the possible connection between the unsteady melt flows and the failure of the alumina control system.

Commercialization Plan

The results of the research, the description of the model, and the outcome of the calibration procedure will be made available to the aluminum industry. This will be achieved through publication of technical articles in professional journals and presentation of reports at relevant symposia and conferences.

Project Partners

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